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(54) Title of the Invention: Laser heat treatment method and laser heat treatment device

(57) [Abstract] (amended)

[Object]

30 Providing a laser heat treatment method for forming a film material over a
substrate superior in crystallinity in order to realize a high-mobility thin film transistor.

[Solution]

A laser heat treatment method where the same portion of a film material 9 over a substrate is irradiated with each of first pulse laser light 3 and second pulse laser light 4, each having a different absorption coefficient with respect to the film material over the substrate, by being converged in a linear shape.

[Scope of Claim]**[Claim 1]**

A laser heat treatment method for performing heat treatment by absorbing laser light in a film material over a substrate, wherein a same portion of the film material over the substrate is irradiated with each of a first pulse laser light and a second pulse laser light, each having a different absorption coefficient with respect to the film material over the substrate, by being converged in a linear shape.

[Claim 2]

A laser heat treatment method according to claim 1 characterized in that the first pulse laser light is a pulse laser light in an ultraviolet region or a vacuum ultraviolet region, and the second pulse laser light is a pulse laser light in a visible region.

[Claim 3]

A laser heat treatment method according to claim 2 characterized in that the first pulse laser light is an excimer laser light or a fluorine laser light.

[Claim 4]

A laser heat treatment method according to claim 2 or 3 characterized in that the second pulse laser light is a harmonic of a Q-switch oscillation solid-state laser where an Nd ion-doped or Yb ion-doped crystal, or glass is used as an excitation medium.

[Claim 5]

A laser heat treatment method according to any one of claims 1 to 4 characterized in that a timing gap between irradiation of the first pulse laser light and irradiation of the second pulse laser light is 200 nsec or less.

[Claim 6]

A laser heat treatment method according to any one of claims 1 to 5

characterized in that an amorphous or polycrystalline silicon film is used as the film material over the substrate.

[Claim 7]

A laser heat treatment method according to claim 6 characterized in that an
6 irradiation energy density of the first pulse laser in the surface of the amorphous or polycrystalline silicon film is 1000 mJ/cm^2 or less and 100 mJ/cm^2 or more.

[Claim 8]

A laser heat treatment method according to claim 6 or 7 characterized in that an
10 irradiation energy density of the second pulse laser in the surface of the amorphous or polycrystalline silicon film is 1500 mJ/cm^2 or less and 100 mJ/cm^2 or more.

[Claim 9]

A laser heat treatment device, for performing heat treatment by shaping laser
light from a laser light source into a linear-shape beam, irradiating a film material over a substrate therewith, and absorbing the laser light in the film material over the substrate,
15 characterized by comprising a first pulse laser light source and a second pulse laser light source where first pulse laser light and second pulse laser light, each having a different absorption coefficient with respect to the film material over the substrate, are generated.

[Claim 10]

A laser heat treatment device according to claim 9 characterized in that the first
20 pulse laser light source is a laser light source in an ultraviolet region or a vacuum ultraviolet region, and the second pulse laser light source is a pulse laser light source in a visible region.

[Claim 11]

A laser heat treatment device according to claim 10 characterized in that the
25 first pulse laser light source is an excimer laser or a fluorine laser.

[Claim 12]

A laser heat treatment device according to claim 10 or 11 characterized in that
the second pulse laser light source is a harmonic of a Q-switch oscillation solid-state laser where an Nd ion-doped or Yb ion-doped crystal, or glass is used as an excitation
30 medium.

[Claim 13]

A laser heat treatment device according to any one of claims 9 to 12 characterized in that an optical axis of the first pulse laser light and an optical axis of the second pulse laser light, each with which the film material over the substrate is
5 irradiated, are coincided with each other.

[Claim 14]

A laser heat treatment device according to any one of claims 9 to 12 characterized in that the optical axis of the first pulse laser light and the optical axis of the second pulse laser light, each with which the film material over the substrate is
10 irradiated, are different.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention pertains]

15 The present invention relates to a laser heat treatment method for forming a polycrystalline silicon film superior in crystallinity in order to realize a high-mobility thin film transistor, and a laser heat treatment device.

[0002]

[Related Art]

20 At present, a pixel portion of a liquid crystal panel constitutes an image by a switching of a thin film transistor which is manufactured with an amorphous or polycrystalline silicon film over glass or a synthesized quartz substrate. If a driver circuit (mainly formed outside, independently) for driving the pixel transistor can be constituted at the same time over this panel, a significant advantage can be obtained in
25 terms of manufacturing cost, reliability, or the like of the liquid crystal panel. However, at present, a silicon film which constitutes an active layer of a transistor has poor crystallinity; therefore, performance of a thin film transistor typified by mobility is low; thus, it is difficult to manufacture an integrated circuit where high speed and high performance are required. Generally, heat treatment by a laser is performed as a
30 method for improving crystallinity of a silicon film, the object of which is to realize a

high-mobility thin film transistor.

[0003]

A relation between crystallinity of a silicon film and mobility of a thin film transistor will be explained as below. A silicon film obtained by laser heat treatment is generally polycrystalline. Crystal defects locally exist in a polycrystal crystal grain boundary, which obstructs carrier mobility of an active layer of a thin film transistor. Thus, in order to increase mobility of the thin film transistor, the number of times that a carrier traverses while moving in the active layer is preferably reduced and a crystal defect density is preferably diminished. It is an object of laser heat treatment to form a polycrystalline silicon film where there is a large crystal grain size and few crystal defects in a crystal grain boundary.

[0004]

FIG. 11 is a view showing an example of conventional laser heat treatment device. Herein, reference numeral 51 denotes an excimer laser (KrF (wavelength: 248 nm), XeCl (wavelength: 308 nm), or the like) which is a typical pulse laser light source of less than 350 nm for emitting ultraviolet light; 52, excimer laser light; 53, a beam homogenizer for making a beam intensity distribution uniform; 54, a convergence optical system for converging a beam; 55, an amorphous silicon film; and 56, glass or a quartz substrate.

[0005]

Next, a conventional laser heat treatment method will be explained. The amorphous silicon film 55 is irradiated thereover with the excimer laser light 52 emitted from the excimer laser 51 by the convergence optical system, through the beam homogenizer 53. The amorphous silicon film 55 in the irradiated region is melted by irradiation with the excimer laser light 52. Thereafter, the melted silicon is recrystallized as the temperature decreases, thereby forming a polycrystalline silicon film. However, an average crystal grain size of the polysilicon that is obtained by the heat treatment with excimer laser light is a few 100 nm, which is extremely small. This is because a pulse time width of an excimer laser generally has only a few 10 nsec; thus, the time until the silicon is recrystallized is short and a large grain size cannot be

grown.

[0006]

As an example of dependency against an energy density of laser light irradiation of mobility (n-channel) of a MOS transistor which is manufactured by using the polycrystalline silicon film formed as described above as an active layer, one in Reference 1 (DIGEST OF TECHNICAL PAPERS AM-LCD 96, TFTp2-4, pp113-116(1996)) is described. This is an example where a KrF excimer laser is used as a laser light source 51, and an amorphous silicon film 55 has a thickness of 50 nm. Although the result obtained in accordance with an irradiation condition varies in some extent, maximum mobility of $100 \text{ cm}^2/\text{Vs}$ can be obtained under irradiation intensity of 260 mJ/cm^2 . However, dependency of the mobility against an irradiation energy density is high, and 80% or more of the maximum mobility can be obtained only within a range of $\pm 5 \text{ mJ/cm}^2$. Accordingly, in introducing the same method to a production line, there is a problem that there is variation in characteristics of a manufactured transistor, unless a laser output and convergence of an optical system are controlled extremely properly. This is because, since absorptance of the excimer laser light in silicon is large, the melted state differs with slight variation in an irradiation energy density; thus, it is considered that a re-crystallization process is changed.

[0007]

In addition, in Japanese Published Patent Application No. H8-148423, it is described that an amorphous silicon film is melted and recrystallized by two laser light of first laser light and second laser light. However, here, it is described that either laser light having the same wavelength as the first laser light or laser light having a wavelength that is absorbed in a substrate is used so as to use the second laser light as auxiliary heating. Moreover, it is suggested to use excimer laser light as the first laser light.

[0008]

[Problems to be Solved by the Invention]

With a conventional typical laser heat treatment method where an excimer laser is used as a light source, since a pulse time width of laser light is short and a film is

absorbed much, a surface is heated; thus, crystal growth is not performed sufficiently in a horizontal direction. Even when the second laser light having the same wavelength is used as auxiliary heating, still, only a surface is heated and only a crystal having a small crystal grain size is obtained. Accordingly, there is a problem that mobility of a thin film transistor can be obtained only with a low value of $100 \text{ cm}^2/\text{Vs}$ at the maximum and approximately $60 \text{ cm}^2/\text{Vs}$ in general. Moreover, since dependency of the mobility against an irradiation energy density is extremely high, certain mobility cannot be obtained; thus, it is problematic that there is variation in characteristics of a manufactured transistor.

10 [0009]

It is an object of the present invention to provide a laser heat treatment method for forming a thin film superior in crystallinity which is necessary for manufacturing a high-performance thin film transistor, and a laser heat treatment device.

[0010]

15 It is a second object of the present invention to provide a laser heat treatment method which has high productivity and stability, and a laser heat treatment device.

[0011]

[Means for Solving the Problem]

20 According to a laser heat treatment method in claim 1 of the present invention, the same portion of a film material over a substrate is irradiated with each of first pulse laser light and second pulse laser light, each having a different absorption coefficient with respect to the film material over the substrate, by being converged in a linear shape.

[0012]

25 According to a laser heat treatment method in claim 2 of the present invention, the first pulse laser light is a pulse laser light in an ultraviolet region or a vacuum ultraviolet region, and the second pulse laser light is a pulse laser light in a visible region.

[0013]

30 According to a laser heat treatment method in claim 3 of the present invention,

the first pulse laser light is an excimer laser light or a fluorine laser light.

[0014]

According to a laser heat treatment method in claim 4 of the present invention, the second pulse laser light is a harmonic of a Q-switch oscillation solid-state laser
5 where an Nd ion-doped or Yb ion-doped crystal, or glass is used as an excitation medium.

[0015]

According to a laser heat treatment method in claim 5 of the present invention, a timing gap between irradiation of the first pulse laser light and irradiation of the
10 second pulse laser light is 200 nsec or less.

[0016]

According to a laser heat treatment method in claim 6 of the present invention, an amorphous or polycrystalline silicon film is used as the film material over the substrate.

15 [0017]

According to a laser heat treatment method in claim 7 of the present invention, an irradiation energy density of the first pulse laser in the surface of the amorphous or polycrystalline silicon film is 1500 [sic] mJ/cm² or less and 100 mJ/cm² or more.

[0018]

20 According to a laser heat treatment method in claim 8 of the present invention, an irradiation energy density of the second pulse laser in the surface of the amorphous or polycrystalline silicon film is 1000 [sic] mJ/cm² or less and 100 mJ/cm² or more.

[0019]

According to a laser heat treatment device in claim 9 of the present invention,
25 the device includes a first pulse laser light source and a second pulse laser light source where first pulse laser light and second pulse laser light, each having a different absorption coefficient with respect to the film material over the substrate, are generated.

[0020]

According to a laser heat treatment device in claim 10 of the present invention,
30 the first pulse laser light source is a laser light source in an ultraviolet region or a

vacuum ultraviolet region, and the second pulse laser light source is a pulse laser light source in a visible region.

[0021]

According to a laser heat treatment device in claim 11 of the present invention,
5 the first pulse laser light source is an excimer laser or a fluorine laser.

[0022]

According to a laser heat treatment device in claim 12 of the present invention,
the second pulse laser light source is a harmonic of a Q-switch oscillation solid-state
laser where an Nd ion-doped or Yb ion-doped crystal, or glass is used as an excitation
10 medium.

[0023]

According to a laser heat treatment device in claim 13 of the present invention,
an optical axis of the first pulse laser light and an optical axis of the second pulse laser
light, each with which the film material over the substrate is irradiated, are coincided
15 with each other.

[0024]

According to a laser heat treatment device in claim 14 of the present invention,
the optical axis of the first pulse laser light and the optical axis of the second pulse laser
light, each with which the film material over the substrate is irradiated, are different.

20 [0025]

[Embodiment Mode of the Invention]

Embodiment mode 1 FIG. 1 is a structural view of a laser heat treatment
device of the present invention. Reference numeral 1 denotes a first pulse laser light
source; 2, a second pulse laser light source; 3, first pulse laser light; 4, second pulse
25 laser light; 5, an attenuator of the first pulse laser light; 6, an attenuator of the second
pulse laser light; 7, an optical system of the first pulse laser light for molding a linear
beam; 8, an optical system of the second pulse laser light for molding a linear beam; 9,
an amorphous silicon film which is a film material over a substrate; and 10, a substrate.
The substrate 10 is located on a translation stage, which enables laser heat treatment in a
30 broad area.

[0026]

Next, a laser heat treatment method will be explained. After adjusting light intensity of the first pulse laser light 3 emitted from the first pulse laser light source 1 with the attenuator 5, the pulse laser light 3 is molded into a linear beam in the reference numeral 7 and the amorphous silicon film 9 is irradiated therewith. The second pulse laser light 4 is oscillated from the second pulse laser light source 2 at the same time as a pulse rising time of the first pulse laser light 3 or only after a specific time to adjust light intensity with the attenuator 6. Thereafter, the pulse laser light is molded into a linear beam in the reference numeral 8 and the amorphous silicon film 9 is irradiated therewith. At this time, as shown in FIG. 2, a width direction of a linear area, which is irradiated with the second pulse laser light, in the surface of the amorphous silicon film have to include a width direction of a linear area, which is irradiated with the first pulse laser light. In other words, in the surface of the amorphous silicon film, the width of the second pulse laser light needs to be wider than the width of the first pulse laser light.

[0027]

Here, if excimer laser light is used as the first laser light, and irradiation of the second pulse laser light whose absorption coefficient of the amorphous silicon film is lower than that of the excimer laser light and whose wavelength, which is absorbed in the amorphous silicon film, is performed simultaneously in terms of time or with a slight delay time provided, light energy in a recrystallization process is additionally compensated. Therefore, the recrystallization time can be prolonged and the crystal grain size can be increased. Specifically, as the first pulse laser light, laser light in an ultraviolet region or a vacuum ultraviolet region of an excimer laser such as KrF or XeCl, or a fluorine laser can be used because of a sufficiently high absorption coefficient with respect to silicon. In addition, as the second pulse laser light, pulse laser light in a visible region where an absorption coefficient thereof becomes lower than that of the first pulse laser light is appropriate. In other words, a harmonic of a Q-switch oscillation solid-state laser where an Nd ion-doped or Yb ion-doped crystal, or glass is used as an excitation medium such as an Nd:YAG laser, an Nd:YLF laser or a Yb:YAG laser, or an Nd: glass laser or a Yb: glass laser can be used.

[0028]

An example of actually using a KrF excimer laser as the first pulse laser light and a second harmonic of an Nd: YAG laser as the second pulse laser light will be explained. A pulse time width is a half value, which is 15 nsec of the KrF excimer laser and 60 nsec of the second harmonic of the Nd: YAG laser. The role of the first pulse laser light is to generate recrystallization by melting the amorphous silicon film. Therefore, an excimer laser that oscillates ultraviolet light having a high absorption coefficient with respect to silicon was selected. The second pulse laser light has a role of prolonging the recrystallization time. Thus, since the silicon film is melted at the time of irradiation, excessively strong light intensity is not necessary (when irradiation of light with strong intensity is performed, laser ablation occurs, thereby peeling the silicon film from the substrate). Rather, it is important for prolonging the recrystallization time that the pulse time width is long. Therefore, a second harmonic of an Nd: YAG laser where an absorption coefficient with respect to silicon is not too high and a pulse time width is long was selected.

[0029]

Note that, in this Embodiment Mode 1, the two laser light have a different optical axis as shown in FIG. 1. In other words, since irradiation of the two laser light may be performed from an arbitrary direction, the laser oscillator can be freely located; thus, a device design and the production becomes easy.

[0030]

Embodiment Mode 2 In Embodiment Mode 2, timing of the irradiation of the first pulse laser light and the second pulse laser light will be described. The change over time of a temperature in a surface of the amorphous silicon film by the laser light irradiation was obtained by a simulation. As shown in FIG. 3, a single dimension model where heat, which is introduced into the amorphous silicon film by the laser light irradiation, is scattered in all direction to a substrate is considered as a computation model. Note that heat loss due to radiation from the surface is not taken into consideration. First, FIG. 4 shows a simulation result of the change over time of the surface temperature in a case of irradiation with KrF excimer laser light with an

irradiation energy density of 200 mJ/cm^2 . A horizontal axis (time) of the figure denotes time after the rising of a pulse, whereas a vertical axis (temperature) denotes the surface temperature. A surface melt time which is almost the same as the recrystallization time is approximately 80 nsec. Next, simulation results in a case of emitting the second harmonic of the Nd: YAG laser whose irradiation energy density is 300 mJ/cm^2 to overlap with delay times of 0 nsec, 50 nsec, and 100 nsec are each shown in FIGS. 5 (a), (b), and (c). According to these results, it is predicted that there is no advantageous effect of the recrystallization time delay by overlapping irradiation of the second laser light with 10 nsec or more. However, as a result of actually conducting an experiment, it is confirmed that there is an advantageous effect of overlapping up to the delay time of 200 nsec, according to observation of an average crystal grain size of a polycrystalline silicon film that is formed with the use of a microscope. Thus, the delay time within 200 nsec, preferably within 100 nsec is appropriate.

15 [0031]

Embodiment Mode 3 In Embodiment Mode 3, an average crystal grain size of a polycrystalline silicon film formed of an amorphous silicon film according to a laser heat treatment method of the present invention will be described. A KrF excimer laser was used as the first laser, and a second harmonic of an Nd: YAG laser is used as the second laser. FIG. 6 shows a result of irradiation with a second harmonic of the Nd: YAG laser with a delay time of 25 nsec by fixing the irradiation energy density of the KrF excimer laser to 200 mJ/cm^2 . In the figure, a horizontal axis denotes an irradiation energy density (YAG 2ω energy density) of the second harmonic of the Nd: YAG laser, whereas a vertical axis denotes an average crystal grain size. The average crystal grain size of a polycrystalline silicon film that is formed by heat treatment only with the KrF excimer laser was $\sim 100 \text{ nm}$. However, an average crystal grain size of a polycrystalline silicon film that is obtained by overlapping the second harmonic of the Nd: YAG laser to have irradiation was approximately $1.2 \text{ }\mu\text{m}$ at most. Since movement of carriers in an active layer of a MOS transistor is obstructed due to a defect in each crystal grain boundary, it is essential to increase a crystal grain size in order to

improve the mobility of a MOS transistor. Accordingly, increase in a crystal grain size according to a laser heat treatment method of the present invention was proved.

[0032]

Embodiment Mode 4 In Embodiment Mode 4, a MOS transistor
5 manufactured using a polycrystalline silicon film formed of an amorphous silicon film
by a laser heat treatment method of the present invention will be described. As for an
evaluation of characteristics, mobility which is a typical parameter of the MOS
transistor is used. A KrF excimer laser was used as the first pulse laser light source,
whereas a second harmonic (2ω) of an Nd: YAG laser was used as the second pulse
10 laser light source. First, FIG. 7 shows dependency of an irradiation energy density
(fluence) of n-channel mobility of a MOS transistor manufactured using a
polycrystalline silicon film, for comparison, which is formed by performing heat
treatment only with a KrF excimer laser. As apparent from the figure, there is only
mobility of approximately $60 \text{ cm}^2/\text{Vs}$ at most. Next, a second harmonic (2ω) of an Nd:
15 YAG laser having various irradiation energy densities were overlapped to have
irradiation by fixing the irradiation energy density of the KrF excimer laser to 240
 mJ/cm^2 . At this time, three types of delay time, 25 nsec, 50 nsec, and 100 nsec, were
provided. The delay times of the n-channel mobility of the MOS transistor
manufactured using the polycrystalline silicon film thus formed are each shown in FIGS.
20 8 (a), (b), and (c). According to these experiment results of the present invention, heat
treatment only with a KrF excimer laser having an irradiation energy density of 240
 mJ/cm^2 has a mobility of approximately $30 \text{ cm}^2/\text{Vs}$; however, it was found that a
mobility of approximately $120 \text{ cm}^2/\text{Vs}$, which is a value four times as much as the heat
treatment only with the KrF excimer laser, is obtained by overlapping the second
25 harmonic of the Nd: YAG laser to have irradiation.

[0033]

Embodiment Mode 5 In Embodiment Mode 5, dependency of an
irradiation energy density of a KrF excimer laser with respect to n-channel mobility of a
MOS transistor, in a case of using a KrF excimer laser as the first pulse laser light
30 source and using a second harmonic of an Nd: YAG laser as the second pulse laser light

source will be described. FIG 9 shows an experiment value indicating a relation of mobility with respect to an irradiation energy density of the excimer laser, in a case where the single KrF excimer laser (a line denoted by EXL in the figure) and a case where a KrF excimer laser is used as the first laser and a second harmonic of an Nd: YAG laser is used as the second laser (a line denoted by EXL+YAG 2 ω in the figure). As apparent from the figure, when the excimer laser and the Nd: YAG laser are used, mobility higher than that obtained by the single excimer laser can be obtained. Additionally, when the excimer laser and the Nd: YAG laser are used, dependency of the irradiation energy density of the excimer laser is extremely low, compared with a narrow range of the irradiation energy density of the excimer laser that can obtain high mobility in the case of the single excimer laser. In other words, when the excimer laser and the Nd: YAG laser are used, there is few adverse effect due to the output variation of the excimer laser.

[0034]

15 Embodiment mode 6 In Embodiment Mode 6, an irradiation energy density of the first pulse laser light will be described. As for the first pulse laser light, ability to make an amorphous silicon film a state capable of recrystallizing after melted is required, and a pulse laser in a vacuum ultraviolet region or an ultraviolet region is appropriate through an absorption coefficient relation. The longer a wavelength becomes, the lower an absorption coefficient becomes. However, when a laser heat treatment experiment is conducted with a XeCl excimer laser which is a laser having a comparatively long wavelength in an ultraviolet region, ablation occurs and a film is peeled from a substrate with an irradiation energy density of 1000 mJ/cm² or more. In addition, a lower limit of the irradiation energy density can be defined as 100 mJ/cm² according to a laser heat treatment experiment using a KrF excimer laser which is a typical laser in an ultraviolet region having a high absorption coefficient.

[0035]

 Embodiment Mode 7 In Embodiment Mode 7, an irradiation energy density of the second pulse laser light will be described. A liquid state where an amorphous silicon film is melted by the first laser light irradiation is irradiated with the

second pulse laser light. The delay of the recrystallization time is a role thereof. It is 100 mJ/cm² or more that the delay of the recrystallization time has an advantageous effect. In addition, an irradiation energy density needs to be one where ablation does not occur. When a second harmonic of an Nd: YAG laser which is typical as the second pulse laser light is used, ablation occurred with 1500 mJ/cm² or more. Therefore, the irradiation energy density of the second pulse laser light is appropriately 1500 mJ/cm² or less and 100 mJ/cm² or more.

[0036]

Embodiment Mode 8 In Embodiment Mode 8, another method for performing irradiation with two laser light in the laser heat treatment method of the present invention will be described. FIG. 10 is a view showing a laser heat treatment device that realizes the laser heat treatment method according to Embodiment Mode 8. In the figure, reference numerals 1 to 10 denote the same members as those in FIG. 1. Reference numeral 11 denotes a dichroic mirror or a polarization beam splitter, which transmits the first pulse laser light and reflects the second pulse laser light, so that optical axes of the first pulse laser light and the second pulse laser light, each with which a film material over a substrate is irradiated, are coincided with each other. In other words, a characteristic of this Embodiment Mode 8 is that the optical axes of the two laser light each with which a film material over a substrate is irradiated, is the same. Since the two laser light are overlapped in advance with the dichroic mirror or polarization beam splitter 11, adjustment of the optical axes at a target position becomes unnecessary; thus, laser heat treatment can be performed easily.

[0037]

[Effect of the Invention]

As described above, according to a laser heat treatment method and a laser heat treatment device of the present invention, where heat treatment is performed by absorbing laser light in a film material over a substrate in the laser heat treatment method, the same portion of the film material over the substrate is irradiated with each of first pulse laser light and second pulse laser light, each having a different absorption coefficient with respect to the film material over the substrate, by being converged in a

linear shape. Therefore, there is an advantageous effect that a high-quality thin film which is appropriate to manufacture a thin film transistor having a large crystal grain size and high mobility can be obtained.

[0038]

5 In addition, in a laser heat treatment method and a laser heat treatment device of the present invention, the first pulse laser light is considered as pulse laser light in an ultraviolet region or a vacuum ultraviolet region, and the second pulse laser light is considered as pulse laser light in a visible region; therefore, there is an advantageous effect that a high-quality thin film which is appropriate to manufacture a thin film transistor having a certainly large crystal grain size and high mobility can be obtained.

10

[0039]

Moreover, a laser heat treatment method and a laser heat treatment device of the present invention, in which an excimer laser (ArF, KrF, or XeCl) or a fluorine laser is used as the first laser light, has an advantageous effect that stable laser treatment with high productivity can be performed.

15

[0040]

Further, a laser heat treatment method and a laser heat treatment device of the present invention, in which a harmonic of a Q-switch oscillation solid-state laser where an Nd ion-doped or Yb ion-doped crystal, or glass is used as an excitation medium is used, has an advantageous effect that effective laser heat treatment can be performed.

20

[0041]

Still further, a laser heat treatment method of the present invention, in which a timing gap between irradiation of the first pulse laser light and irradiation of the second pulse laser light is 200 nsec or less, has an advantageous effect that a high-quality thin film which is appropriate to manufacture a thin film transistor having a certainly large crystal grain size and high mobility can be obtained.

25

[0042]

Furthermore, a laser heat treatment method of the present invention, in which an amorphous or polycrystalline silicon film is used as the film over the substrate, can manufacture a high-mobility thin film transistor.

30

[0043]

Furthermore, a laser heat treatment method of the present invention, in which an irradiation energy density of the first laser light in a surface of an amorphous or polycrystalline silicon film is 1000 mJ/cm^2 or less and 100 mJ/cm^2 or more, can perform high-quality heat treatment.

[0044]

Furthermore, a laser heat treatment method of the present invention, in which an irradiation energy density of the second laser light in a surface of an amorphous or polycrystalline silicon film is 1500 mJ/cm^2 or less and 100 mJ/cm^2 or more, can form a thin film superior in crystallinity.

[0045]

Furthermore, a laser heat treatment device of the present invention, in which optical axes of the first pulse laser light and the second pulse laser light at the time of laser light irradiation are coincided with each other to have irradiation, have an advantageous effect that adjustment of the optical axes at a target position becomes unnecessary.

[0046]

Furthermore, a laser heat treatment device of the present invention, in which the first laser light and the second laser light at the time of laser light irradiation have a different optical axis; that is, since irradiation of the two laser light may be performed from an arbitrary direction, the laser oscillator can be freely located; thus, a device design and the production become easy.

[Brief Description of the Drawings]

FIG1 is an outline view showing a laser heat treatment device describing Embodiment Mode 1 of the present invention.

FIG2 is a view expressing a relative position of an irradiation area by two laser light according to Embodiment Mode 2 of the present invention.

FIG. 3 is a view explaining a computation model of a heat conductive simulation at the time of laser light irradiation for explaining Embodiment Mode 2 of the present invention.

FIG.4 is a graph showing a simulation result of change over time of a temperature in a surface of a silicon film by KrF excimer laser irradiation for explaining Embodiment Mode 2 of the present invention.

FIGS.5 are graphs each showing a simulation of change over time of a temperature in a surface of a silicon film in a case of irradiation of a second harmonic of an Nd: YAG laser at the same time as KrF laser excimer laser irradiation, after 50 nsec, or after 100 nsec for explaining Embodiment Mode 2 of the present invention.

FIG.6 is a graph showing an average grain size of a polycrystalline silicon film obtained by a laser heat treatment method for explaining Embodiment Mode 3 of the present invention.

FIG.7 is a graph showing n-channel mobility of a MOS transistor manufactured using a polycrystalline silicon film that is obtained by laser heat treatment only with a laser heat treatment method for explaining Embodiment Mode 4 of the present invention.

FIGS.8 are graphs each showing n-channel mobility of a MOS transistor manufactured using a polycrystalline silicon film that is obtained by setting delay times at 25 nsec, 50 nsec, and 100 nsec in a laser heat treatment method for explaining Embodiment Mode 4 of the present invention.

FIG. 9 is a graph explaining dependency of an irradiation energy density of a KrF excimer laser for explaining Embodiment Mode 5 of the present invention.

FIG.10 is an outline view showing a laser heat treatment device describing Embodiment Mode 8 of the present invention.

FIG.11 is an outline view showing a conventional laser heat treatment device.

[Description of the Numerals]

1. first pulse laser light source, 2. second pulse laser light source, 3. first pulse laser light, 4. second pulse laser light, and 9. film material over a substrate.

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